Chapter

Winemaking in Cold Regions with Buried Viticulture in China

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Abstract

China has a long history of grape cultivation and wine making, and it has grown to be one of the most important countries in terms of grape cultivation, wine production, and wine consumption. According to meteorological and geographical regionalization, China's wine production area has been divided into 11 regions, the majority of which are located in cold and mid-temperate regions in northern China, where vines must be buried in winter and unearthed in spring. In China, the main cultivated grape varieties are similar, with the red variety accounting for more than 80% of the total, while the white variety represents just 20%. Currently, Cabernet Sauvignon is the most widely planted variety, but Marselan, another red variety, have recently shown good prospects. Wild grape species such as *Vitis amurensis*, *Vitis davidii*, and *Vitis quinquangularis* are widely planted in northern and southern China because of their good resistance to local climate. This chapter highlights some common wild grape varieties in China, as well as the wines made from them. Also, some winemaking pretreatment techniques are reported.

Keywords: wine, China regions, buried viticulture, wild species, pretreatment technics

1. Introduction

China has an ancient history of beverage making. A fermented beverage of rice, honey, and fruit (hawthorn fruit and/or grape) absorbed into pottery jars from the early Neolithic village of Jiahu in China's Henan province indicate the beverage's earlier existence, dated back to 7000 B.C [1]. The viticulture and enology history in China could be traced back to the Han dynasty (138 B.C.). Zhang Qian was the first to introduce vines and winemaking techniques into China through the Silk Road. Since then, wine has been made in all of ancient China's dynasties [2], although it did not become popular until the Tang dynasty (618–907 A.D.). As a symbol of Chinese wine culture, many famous poetries were written and spread for thousands of years. During the Yuan dynasty (1271–1368 A.D.), the government instructed wine and other fruit beverages to be a replacement for cereal grain beverages. Moreover, an agricultural science literature known as 'Nong Sang Ji Yao' also recorded viticultural and winemaking practices in detail, which formed the most prosperous period of the wine industry in ancient China's history. The modern Chinese wine industry began at the end of the 19th Century when a high-ranking official brought more than 100 *Vitis vinifera* vines from Europe, and the first winery Changyu was established in Shandong province in 1892, which still holds the

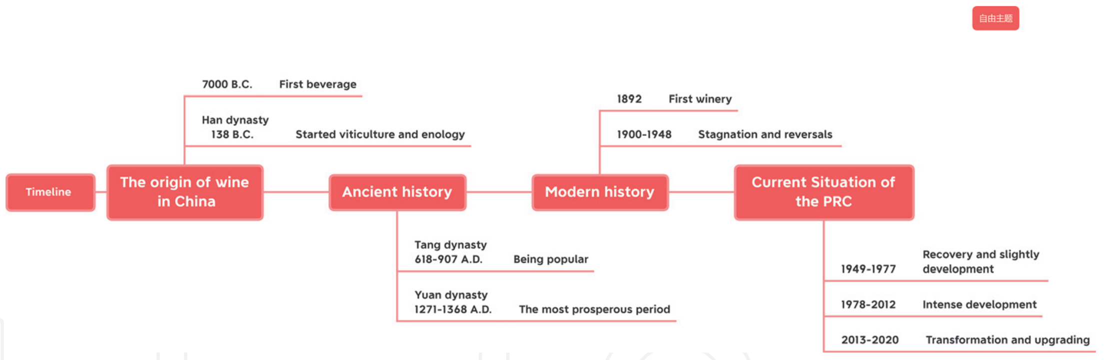

Figure 1.
Summary of the history and development of China wine industry.

leading position in Chinese wine today. With the birth of the People's Republic of China (PRC) in 1949, the Chinese government became heavily involved in the country's wine industry, expanding vineyard areas, wineries, and wine production. The contemporary wine industry underwent recuperation and considerable development at this time, but it was not until the reform and opening-up policy in 1978 that wine output increased substantially [3]. After decades of rapid growth, total wine production decreased year by year beginning in 2013, but both import volume and total wine consumption increased, indicating that China's wine market is still expanding (**Figure 1**). As one of the biggest and dynamic international markets, wines from all over the world gathered, competed, traded, and merged, causing China's wine industry to progress and upgrade over and over again. Despite this, opportunities and challenges coexisted in such a market [2].

2. Grape and wine industry in China

In the past decades, the area used for grape cultivation and the total wine production and consumption in China has rapidly expanded. Relevant statistics regarding the grape and wine industry since the birth of the People's Republic of China are shown in **Table 1**.

As can be seen from **Table 1** below, China has accomplished great success in the grape and wine industry with unprecedented speed, both in terms of vineyard area, wine production, and consumption. According to the latest International Organization of Vine and Wine (OIV) report on the world Viti vinicultural situation (2019 and 2020) [4, 5], the size of the total world area under vines (regardless of the final destination of the grapes and including vineyards not yet in production) remained stable at 7.3 mha (millions of hectares) in 2020. With 961 kha, Spain remains the clear leader in terms of cultivated vine area, followed by France (797 kha) and China (785kha).

The world wine production (excluding juice and musts) in 2020 was estimated at 258 mhl as Italy (49.10 mhl) maintained its position as the world's leading producer, followed by France (46.60 mhl) and Spain (40.70 mhl). China, on the other hand, produced 6.60 mhl. The data shows a slight drop in global wine consumption (estimated at around 234 mhl) in 2020 because of the COVID-19 outbreak. The United States (33.0 mhl), France (24.7mhl), and Italy (24.5 mhl) maintained their top three positions as the world's largest consuming countries with China ranking sixth with 12.4 mhl consumption in the world.

In China, Red varieties account for nearly 80% of the total vineyard area, while the white varieties proportion was only 20% [3]. Red wine is also far more popular

Year	Vineyard area (kha)	Grape production (mt)	Wine production (mhl)	Year	Vineyard area (kha)	Grape production (mt)	Wine production (mhl)
1950	3.2	0.04	0.83(khl)	2000	283	3.28	2.02
1959	18	0.09	0.08	2005	408	5.79	4.34
1965	11.5	0.1	0.12	2010	513	8.14	10.89
1970	/	0.09	0.2	2012	613	10.01	13.82
1975	64	0.12	0.35	2014	689	11.73	11.61
1980	32	0.11	0.78	2016	713	12.63	11.37
1985	87	0.36	2.33	2018	820	13.67	6.29
1990	121	0.86	2.54	2020	785	14.2	6.6
1995	149	1.74	2.29				

Note: *It is estimated that wine grape production area only occupies 10% of the total vineyard.*
Units: *kha, thousands of hectares; mt, millions of tons; khl, thousands of hectolitres; and mhl, millions of hectolitres.*
Source: *National Bureau of Statistics in China (vineyard area and grape production), and China alcoholic drinks association (wine production).*

Table 1.
The vineyard area, grape production, and wine production in China.

in the Chinese market than other types of wine, and a large section of the population refers to such wine as “红酒” (Hóngjiǔ), because of its red color.

3. General climatic and agronomic conditions of wine regions in China

According to administrative division and the meteorological and geographical regionalization, China wine producing regions have been widely categorized into 11 recognized regions [6], including the Northeast, the Eastern Region of Helan Mountain, Beijing-Tianjin-Hebei (also known as Jing-Jin-Ji), Shandong (also known as Jiaodong Peninsula), Old Course of the Yellow River, Loess Plateau, Inner Mongolia, Hexi Corridor, Southwest Alpine, Xinjiang and Others (**Figure 2**).

As can be seen from **Figure 2**, viticulture and enology are widely distributed in China, from 24 to 47°N, 76–132°E. The majority of vineyards are located in northern China, where they are affected by the continental monsoon climate with cold, dry winters and extremely low temperatures of −15°C during the winter. The fatal flaw for grape varieties is not only extremely low temperatures but also large amounts of water evaporation caused by extreme droughts in spring and winter, often known as ‘drought-freezing’. As a result, measures have been adopted to protect vines from the cold and drought during the winter months. One of the most effective methods is to bury the vine in the soil, which is also known as buried viticulture.

In addition, some sub-areas in China’s south and southwest have been identified as wine producing regions. These regions are generally located at a high altitude with a complex ecological condition, also suitable for the cultivation of *Vitis vinifera* species. However, the most planted grapes are traditional Chinese varieties such as *Vitis quinquangularis* and *Vitis heyneana* as well as their hybrid varieties (**Table 2**). The detailed information of China wine production regions, including the location, latitude & longitude, vineyard area (kha), main variety, wine production volume (mhl), meteorology, climatic subdivisions, altitude (m), and agrotype are shown in **Table 2**.

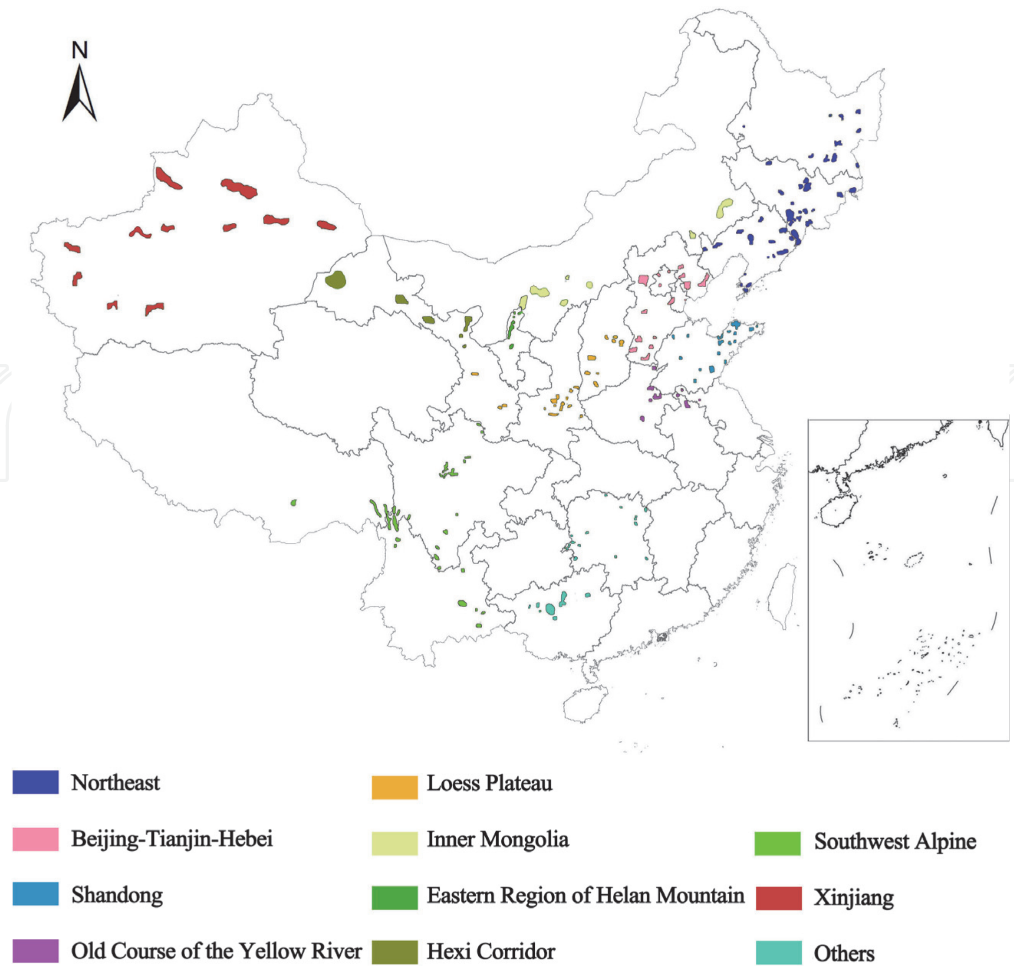

Figure 2.
Chinese wine production regions.

The vineyard area for wine grape in each region can be seen from **Table 2**, with a total of 163.39 kha, however, the CADA report (2018) shows that the wine grape area in China was only 85.19 kha, which could be due to some table grapes that are also used for winemaking being counted in **Table 2**.

In China, the main cultivated grape varieties in most regions are similar. The red grape varieties play a dominant role which occupies more than 80% [3], and among them, Cabernet Sauvignon is the most widely planted variety, followed by Merlot and Cabernet Gernischt (**Table 2**).

Recently, a new red variety, *Vitis vinifera* L.cv. Marselan, which was bred in 1961 by the French National Institute for Agricultural Research (INRA), and introduced in China in 2001, showed good adaptability in China and was considered a new star variety in China wine regions. The parent variety of Marselan is two famous red grape varieties, Grenache and Cabernet Sauvignon. Wines made from Marselan showed both parent characters, with medium-bodied and fine tannins, good color, intense fruity aroma presented in cherry and cassis flavor [8]. Nowadays, Marselan is being planted in Hebei, Shandong, Xinjiang, Ningxia, and Gansu Regions. Some wineries made wines from the single or blended Marselan variety and won lots of important awards. According to some domestic experts, Marselan wine is well suited for Chinese consumers and could be a very potent variety in China.

White grape varieties only represent a small quantity of about 20% in China. Among them, Chardonnay, Italian Riesling, and Riesling are the commonly cultivated varieties in the various regions (**Table 2**). A traditional white grape variety known as Longyan, has the potential to be utilized as both a table grape and a wine grape. As a late-harvested variety, the Longyan grape has been widely cultivated in

Regions	Producing area	Latitude & Longitude	Vineyard area (kha)	Main variety	Wine production (mhl)	Frost-free period (d)		Rainfall mm	Drought index	Climatic subdivisions	Active accumulated temperature (>10°C)	Extreme low temperature °C	Altitude (m)		Agrotype
						Range	Average value						Range	Average value	
Northeast	Jilin, Liaoning, Heilongjiang	39°18′-45° 45′N, 118° 50′-133° 30′E	8.25	*Vitis amurensis* and its hybrid variety: Gongniang No.1, Shuang, Hong, Shuang You, Zuo You Hong, Bei Bing Hong, Gong Zhu Bai, Vidal	1.15	147–222	171	400–1000	0.67–1.61	Cold temperate and mid-temperate semi-humid region	2567–2779	−33.7 ~ −15	12.2–422	207.15	Chernozems
Beijing-Tianjin-Heibei	Changli, Tianjin, Huaizhuo Basin	36°03′-42° 40′N, 113° 27′-119° 50′ E	17.01	Cabernet Sauvignon, Cabernet Gernischt, Melort, Muscat Hamburg, Chardonnay, Italian Riesling, Longyan	0.72	162–228	206	350 ~ 770	0.85–2.26	Warm-temperate semi-arid to semi-humid region	3800–4200	−23.4 ~ −14.2	1.30–629.30	190.78	Cinnamon soil, Fluvo-aquic soil, Brown earth
Shangdong	Jiaodong Peninsula, Central Shandong, Northwestern Shandong, Southern Shangdong	34°22′-38° 23′ N, 114° 47′-122° 43′ E	16.75	Cabernet Sauvignon, Cabernet Gernischt, Melort, Cabernet Franc, Chardonnay, Italian Riesling	3.84	212–241	230	550–950	0.81–1.55	Warm-temperate semi-humid region	3800–4600	−15.3 ~ −10.2	4.80–171.5	68.6	Brown earth

Regions	Producing area	Latitude & Longitude	Vineyard area (kha)	Main variety	Wine production (mhl)	Frost-free period (d)		Rainfall mm	Drought index	Climatic subdivisions	Active accumulated temperature (>10°C)	Extreme low temperature °C	Altitude (m)		Agrotype
						Range	Average value						Range	Average value	
Old Course of the Yellow River	Henan, Anhui, Jiangsu	33°36′-34° 56′N, 114° 49′-117° 12′ E	1.5	Cabernet Sauvignon, Melort, Cabernet Franc, Chardonnay, Italian Riesling, Rkatsiteli, Bacco Noir	1.88	228–245	238	600 ~ 900	0.91–1.25	Warm-temperate semi-humid region	4000	−11.6 ~ −9.78	34.7–110.4	57.8	Yellow moist soil
Loess Plateau	Shanbei plateau, Kuan-Chung Plain, Qinling-Daba Mountain, Central Shanxi, Southern Shangxi	33°21′-39° 35′ N, 107° 59′-113° 01′E	3.74	Cabernet Sauvignon, Melort, Cabernet Gernischt, Yan 73, Meili, Chardonnay, Ugni Blanc, Italian Riesling, Ecolly Bei Bing Hong, Hu Tai	0.34	165–254	213	300 ~ 700	1.19–2.09	Mid-temperate and warm-temperate semi-arid to semi-humid region	3000–4500	−23.5 ~ −8.6	402.9–1134.6	654.2	Black loessial soil, Cultivated loessial soil, Yellow-brown earth, Cinnamon soil
Inner Mongolia	Wuhai	39°15′-39° 52′ N, 106°36′-107°06′ E	6.14	Cabernet Sauvignon, *Vitis amurensis*, Beibinghong	0.03	143–184	169	50–450	1.50–6.91	Cold and mid-temperate arid to semi-arid region	2800–3600	−26.0 ~ −20.2	178.7–1561.4	911.6	Sandy loam soil, Loamy soil, Gravelly soil
Eastern Region of Ningxia Helan Mountain	Yinchuan, Qingtongxia, Hongsibu, Yongning, Helen	37°28′-39° 05′ N, 105°21′-106°80′ E	34	Cabernet Sauvignon, Melort, Cabernet Gernischt, Cabernet Franc, Pinot Noir Chardonnay,	0.34	172–190	183	200–700	4.31–5.22	Cold and mid-temperate arid region	3100–3500	−21.2 ~ −18.9	1092.5–1128.8	1110.9	Sierozems, Eolian sandy soil, Cumulated irrigated soil

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						Range	Average value						Range	Average value	
				Italian Riesling, Riesling											
Hexi Corridor	Wuwei, Zhangye, Jiayuguan	36°46′-40°12′ N, 93°99′-104°43′ E	20.55	Cabernet Sauvignon, Pinot Noir, Melort, Cabernet Gernischt, Chardonnay, Italian Riesling, Vidal *Vitis amurensis*	0.82	141–213	173	37.3–230	2.22–31.42	Cold temperate arid to semi-arid region	3200	−22.7 ~ −14.4	11390–2311.8	1517	Gravelly soil, Sandy loam soil
Xinjiang	North Slope of Tianshan Mountains, Lli Valley, Yanqi Basin, Turpan-Hami Basin	39°30′-44° 10′ N, 80° 28′-96°23′ E	36.7	Cabernet Sauvignon, Melort, Yan 73, Marselan, Syrah Chardonnay, Riesling, Pitit manseng,	0.52	176–242	199	50 ~ 300	3.91–246.45	Mid-temperate arid region	3500–4000	−31.9 ~ −13.6	1.0–1422.0	837.6	Brown desery soil, Gray desery soil, Fluvo-aquic soil
Southwest Alpine	Southwest Sichuan, Western Sichuan Plateau, Shangri-La region, Southeast Yunnan	23°50′-31° 43′N, 99° 70′-103° 49′ E	5.45	Cabernet Sauvignon, Melort, Cabernet Gernischt, Fa-guoyeRose HoneyCrystal	0.31	278–353	273	500 ~ 800	0.66–1.92	Subtropical semi-humid region	3000–5000	−10.6 ~ −0.3	1254.1–3319.0	1986.3	Gravelly sandy loam, Cinnamon soil, Red earth, Lime soil, Brown earth, Red clay soil, Cinnamon soil, Torrid red soil, Sandy soil

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						Range	Average value						Range	Average value	
Others	Northern Hunan, Southeastern Hunan, Hechi	23°47′-29° 57′ N, 108° 47′-113°77′ E	13.3	Vitis *davidii*: Ziqiu, Xiangniang No.1, Vitis *quinquangularis*: Yeniang No.1, Yenaing No.2	0.07	277–365	314		0.44–0.72	Subtropical humid region	>5000	−5.0 ~ −3.6	40.2–355.5	218.6	Red earth, Yellow earth, Lateritic red earth, Humid-thermo ferralitic

Source: *Adapted from Li [6] and Sun [7].*

Table 2.
A detailed description of China wine regions.

Beijing-Tianjin-Heibei, Shandong, and Loess Plateau regions for the development of wine characterized by a green to yellow color, fresh fruity flavor, and good taste [8].

4. Wild grape species and the elaborated wine in China

China has very abundant *Vitis germplasms* in diverse species, which are distributed extensively within the country. Some Chinese wild grape species, *Vitis davidii*, *Vitis quinquangularis*, and *Vitis amurensis*, which have a long history of use in China, were widely planted to support the domestic grape and wine industry as these species showed strong environmental adaptability to the local climate [9]. In many parts of China, the fruit of Vitis wild species has been employed in winemaking whereby wines made from these grapes have a distinctive color, aroma, and taste, quite unlike those made from *Vitis vinifera* [10].

Vitis amurensis and its hybrid varieties are the most important in the Northeast due to their ability to withstand the cold winters, whereas *Vitis davidii* and *Vitis quinquangularis* are widely cultivated in the Southwest Alpine and Other regions due to their ability to withstand the high temperatures and humidity in southern China. The fruit berry characters of these Vitis wild species are similar, with low content of sugar, high content of acids, and deep color, which can result in a wine with low alcohol concentration, high acidity, and astringency. Li [9] and Lan [11] also reported that wines of native Chinese species had relatively higher blue % values and lower red % values.

4.1 *Vitis amurensis*

V. amurensis, which originated in north-eastern China, is now commercially cultivated in many places. The most important trait for this species is cold resistance. *Vitis amurensis* has a strong root system and high growth vigor, allowing it to survive at temperatures as low as −40°C. Besides, this species also showed high resistance to many diseases such as grape white rot and grape anthracnose [12]. Thus, it has been used as a disease-resistant stock as well as the most powerful cold-resistant rootstock to breed materials for resistance to biotic and abiotic environmental factors [12], and it is considered to be an effective way to save inputs in vineyard management by avoiding burying the vines.

Since the 1950s, significant progress has been made in understanding and utilizing wild *V. amurensis* grape germplasm resources in China. Grape researchers conducted a series of selection and domestication experiments on the *V. amurensis* species in Northeast China, and after many years of effort, they have selected a series of good varieties and types (**Figure 3**), as well as a series of work on cultivation and expansion on this variety [13].

As a wine grape, the *V. amurensis* fruit has a unique aroma and distinctive taste with high acidity and bitterness thus was used to make sweet wines [12, 14]. Nowadays, with the breeding of new varieties, *V. amurensis* and its hybrids can be used to make sparkling wine [15], rose wine [16], and ice wine [11]. Some novel techniques, such as carbonic maceration can also be used to improve the quality of *V. amurensis* wine [17].

When Bei Bing Hong (a variety of *V. amurensis*) was used to produced sparkling wine, its esters, carbonyls, alcohols, and terpenes contributed significantly to the aroma profile of the wine. The typical aroma characters of Bei Bing Hong sparkling wine are fruity aromas such as apple, apricot, pear, strawberry, cherry and sweet melon [15]. A mixed brewing method was used to produce rose wine from *Vitis amurensis* Rupr cv. Gongzhubai (white) and Beibinghong (red) grapes [16]. The

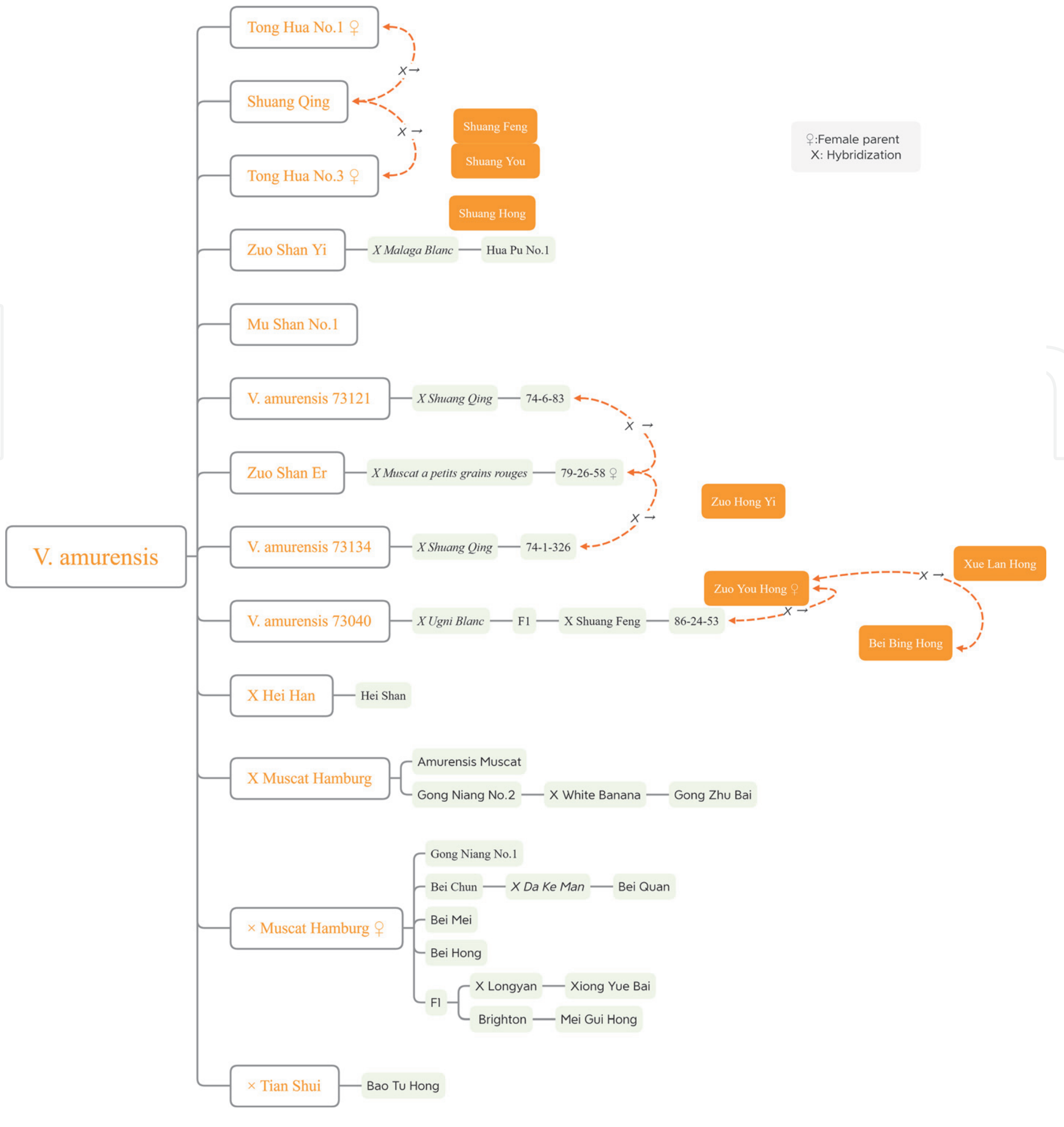

Figure 3.
Elite clones and hybrids varieties of V. amurensis.

fruit of each variety was pressed and the must fermented at low temperatures (11 ~ 12°C). By combining 8% and 12% of Beibinghong wine with Gongzhubai wine, a rose wine with elegance and aroma complexity was produced [16].

Lan [11] studied the evolution of free and glycosidically bound volatile compounds in 'Beibinghong' grape berries during on-vine, over-ripening, and freezing processes. The results showed that the aroma profiles of 'Beibinghong' icewine berries were characterized by C6 compounds, higher alcohols, and terpenoids in free fractions as well as carbonyl compounds, higher alcohols, C6 alcohols, and terpenoids in bound fractions. A striking alteration of the volatile profile of C6 alcohols, higher alcohols, and oxidative terpene derivatives occurred at sub-zero temperatures. These changes were attributed to a series of reactions (biotransformation, oxidation, and anaerobic metabolism) induced by water loss and particularly, freeze–thaw cycles [11].

Anthocyanins are responsible for the color of grapes and wine. Zhao [10] analyzed the anthocyanin profiles of grape berries of *Vitis amurensis*, its hybrids, and their wines. It was found that the anthocyanin profile of the grape cultivars consisted of 17 anthocyanins, including 11 anthocyanin monoglucosides and six anthocyanin diglucosides. However, the wines produced a slightly different result in anthocyanin distribution in the corresponding wines where 15 kinds of anthocyanins, including six diglucosides and nine monoglucosides were detected [10]. Furthermore, pelargonidin-3,5-diglucosides was also found in the grapes and their corresponding wines.

Additionally, Li [9] also revealed that *Vitis amurensis* and its hybrids wines had a higher phenolic percentage of non-coumaroylated 3, 5-O-diglucosidic anthocyanins, while *V. vinifera* wines had a higher phenolic percentage of flavan-3-ols and 3-O-monoglucosidic anthocyanins.

4.2 Vitis davidii (spine grape)

Vitis davidii var. Forex belongs to the East Asian Vitis spp. and is one of the main wild grape species growing in the East Asian region. It is also known as Spine grape, because its shoots, petioles, and veins are densely covered by spines at 1–2 mm long [18]. The spine grape is mainly distributed in the mountains covered by the subtropical rainforest to the south of the Yangtze River. Huaihua county in Hunan province and Chongyi county in Jiangxi province are the most representative regions for spine grapes because of their wide distribution in those areas [19]. As spine grapes originated from the subtropical humid areas of southern China, this variety showed strong tolerances to high temperatures, high humidity, and resistance to diseases, such as spot anthracnose, white rot disease, and anthracnose [19].

Spine grape was used as table grape years ago, because of its larger berry size compared to other wild species, with an average fruit weight between 3.0–4.5 grams, and a total soluble solid range of 14.5%–16.0% [20]. Recently, with the rapid increase of cultivated area, only a small quantity of spine grapes was made available as fresh edible fruit and a major portion tend to be abandoned each year. Researchers have found that the intense process of converting the Spine grape to wine not only prevents the wastage of grape fruits but also brings high economic benefits to local growers [21]. More so, the development of new cultivars also promotes Spine wine production.

Meng analyzed the physicochemical parameters and aromatic components of nine clones of spine grape from Zhongfang County (Hunan Province, China) [22]. The berry weight, total soluble solids, titratable acids (expressed as equivalent of tartaric acid), and pH were found to be in the ranges of 2.08–3.88 g, 9.5–15.4 Brix, 1.99–3.93 g/L, and 3.16–3.77, respectively, indicating that the clones are more suitable for winemaking compared to the wild spine grape.

Flavor compounds are important quality indexes for wine production, which are mainly derived from grape berries, and can be affected by soil, altitude, slope, and cultivation management among others. In two different studies, Meng [22] and Zhao [18] respectively evaluated the free aromatic components and the influence of different altitudes on flavor compounds of Spine grape clones, 'Ziqiu', 'Seputao',' Miputao',' Xiangzhenzhu', 'Tianputao', and' Baiputao'. According to the findings, C6 compounds were the most abundant aromatic components in various spine grape clones, accounting for 71–94% of the total aromatic compounds identified. The most predominant compounds were (E,E)-2,4-hexadienal and (E)-2-hexenal [22]. At the height of 700 meters above sea level, the contents of anthocyanins, non-anthocyanin phenolic compounds, and aroma compounds in 'Seputao' were significantly higher than those at 240 meters and 600 meters altitudes. However, at the altitude of 240 meters, the contents of reducing sugars, anthocyanins, non-anthocyanin phenolic compounds, and aroma compounds in'Ziqiu'were the highest among three altitudes 240, 600, and 700 meters [18].

Meng [19] also investigated the phenolic profiles and antioxidant activity of four spine grapes cultivars (Junzi #1, Junzi #2, Liantang, and Baiyu) from Chongyi County, Jiangxi Province, China. It was revealed that Junzi #1 had the highest phenolic content and the strongest antioxidant capacity, HPLC analysis also showed that the (+)-catechin was the most abundant phenolics while hydroxycinnamic acids were the major phenolic acids [19]. Regarding some individual phenolic compounds, JZ-1 contained the highest p-coumaric acid, coumarin, trans-resveratrol, and (+)-catechin contents, while BY had the highest rutin and quercetin contents.

The same researcher also characterized the phenolic profile of young wines made from spine grape. Like most vinifera wines, flavan-3-ols were the major class of phenolic compounds present in spine grape wines while quercetin-3-rhamnoside was the main singular flavonol [21]. In addition, syringetin-3-glucoside and dihydroquercetin-3-hexoside were the characteristic flavonols of red and white spine grape wines, respectively, while coutaric acid and fertaric acid were the dominant phenolic acids [21].

Organic acids play a key role in grape and wine quality. The acid component of grape berries mainly consists of tartaric acid, malic acid, lactic acid, acetic acid, citric acid, and oxalic acid. The total acidity in *Vitis davidii* Foex fruits is typically higher than in *Vitis Vinifera* varieties, resulting in high acidity in the fermented wine [23] (around 8 grams of tartaric acid per liter of wine after malolactic fermentation), which has been a major constraint on the Spine wine industry.

The effect of deacidification reagents ($KHCO_3$ and $CaCO_3$) on the aroma compounds of spine wine was studied by Li [23]. The results showed that the OAVs of compounds with flavors of fruit, cheese, caramel, and chemical were reduced. However, sensory evaluation revealed that the mouthfeel and aroma characteristics of spine wine were improved after deacidification.

Due to the relatively low sugar content in Spine grapes, ranging from 12.3 to 15.9°Brix, an early winemaking study showed that sugar addition was required for red Spine wine production to improve wine quality [24]. Conversely, this neutral grape characterized by low sugar levels and high acidity is suitable for making distilled spirit-based beverages [25].

Currently, high quality Spine grape spirits are produced by several local wineries and are welcomed by local consumers. Xiang [26] identified the key odor-active volatile compounds in the head, heart, and tail fractions of freshly distilled spirits from Spine grape (*Vitis davidii* Foex) wine. The volatile compounds had considerably varying amounts in the head, heart, and tail fractions due to differences in boiling point and solubility, which resulted in various evolution patterns during distillation. The head fraction was characterized by fruity, fusel/solvent notes owing to higher concentrations of higher alcohols and esters, while the tail fraction had more intense smoky/animal, and sweaty/fatty attributes due to higher concentrations of volatile phenols and fatty acids [26].

4.3 *Vitis quinquangularis* Rehd

Vitis quinquangularis, known locally as the pentagon-leafed grape, is distributed south of the Yellow River in regions that have sufficient sunshine and are at an altitude of <1500 m.

Vitis quinquangularis is an important research grape with high resistance to powdery mildew due to its high resveratrol content [27].

Selection studies have also been conducted on *V. quinquangularis* in the central part of China. Liang [28] revealed that this cultivar contained different anthocyanins compared to *Vitis davidii*. For example the 'Xiangshan No. 4' (*V. quinquangularis*) contains high levels of 3′,4′-substituted anthocyanins, low levels of flavonols, and low 3′,4′-substituted flavan-3-ols, indicating that the F3′H branch pathway is the principal carbon pathway synthesizing mainly 3′,4′-substituted anthocyanins [28].

Also, the grape berries of *Vitis quinquangularis* ripen with low sugar content and high acidity, but with dark-colored skin. Their wines have a characteristic varietal aroma and a pronounced acid and tannic sensation [28, 29].

Fang examined the effects of different processes on the flavor components of wild *V. quinquangularis* wine produced in the Qinba mountain region [30]. The findings demonstrated that alcohol was the most important aroma compound in *V. quinquangularis* wine, with the highest relative contents of benzene ethanol and pentanol. After six months of aging, the aroma quality of carbonic macerated wine was better than that of the traditional process [30].

Liu also proved that carbonic maceration increased the contents of esters, acids, and phenols as well as the species and contents of volatile compounds in wines [31]. The combination of carbonic maceration and malolactic fermentation could result in more volatile compounds in wines, giving such wines a unique taste distinct from traditional wines [31]. Similar results were reported in *V. amurensis* wines, with Pei revealing that carbonic maceration decreased the fruit aroma while increasing the flower aroma and overall aroma quality of *V. amurensis* wine [17].

5. Buried viticulture

In China, most of the viticulture regions are distributed in cold and mid-temperate regions (**Table 2**), these regions are typically affected by the continental monsoon climate with cold, dry winters, and frequent early spring frosts, which can result in severe freezing injury and dehydration risks to branches and roots [32, 33]. It has been acknowledged that, as the main cultivated wine grape variety, the grape and wine quality of *Vitis vinifera* is higher than that of *Vitis labrusca* and various wild species, however, the cold resistance is completely opposite [34]. When the temperature in winter is extremely lower than −15°C, the vines need to be protected to withstand the severe cold, prevent draining, and ensure its safe overwintering. In China, more than 90% of *Vitis vinifera* are distributed in areas where the vines must be buried under a layer of soil during winter (buried viticulture).

In order to choose suitable measures for overwintering, interspecific hybrid breeding, rootstock grafting, wind dispersing cold air, adjusting plant load, soil or material covering, delaying pruning, and other technics were implemented by numerous of researchers all over the world [34, 35]. However, after years of experiments, burying the vines into the soil is still the most effective way to protect vines over winter. In general, the vines are taken down off the trellis after pruning and then buried into the soil (more than 30 cm underground) in the winter, and the soil is removed before the sprouting in the next spring. Both artificial and mechanical methods are used to complete the burying and unearthing of the vines, and this work should be done very carefully to prevent damage to branches and buds. To aid buried viticulture, several cover materials and methods, such as film mulching, industrial cotton, straw mattress, and plastic have been devised and used. Additionally, various types of vine burying and soil removing equipment (or digging machines) have been designed and employed [36].

Because buried management exposes the soil surface in winter and early spring, there is an increased danger of wind erosion and sandstorms, which may cause ecological problems in viticulture regions in northern China. Recently, a new viticultural procedure was reported during winter pruning to ameliorate this phenomenon, by clutching the vine shoots on the wires until next spring. Also, a windbreak was built as a protective function to reduce wind speed, and the dangers of sand storms as well [37].

In conclusion, buried viticulture is labor intensive, costly, and has the potential to cause damage and diseases to branches while also destroying the ecological environment. Buried viticulture further limits mechanized production and all these challenges are serious impediments to China's wine development [34].

6. Winemaking techniques

Nowadays, with a decrease in wine consumption and an increase in imported wines, there is no mention of competition from Chinese liquor -Baijiu, Chinese rice

Technics	Treatment	Mechanism	Major impacts on wine composition	Reference
Berry heterogeneity	Berry classification	Heterogeneity influence fruits weight, diameter, berry density, and soluble solids content	Smaller fruits reduced the contents of malic acid and pH value, increased wine color, phenolic substances, varied the aroma substances and titratable acids contents	[38]
Cold maceration	Temperature below 10°C for 3-7 days	Lower temperature improved the maceration time and substance from grape skins	Improving wine color and aroma	[39]
Carbonic Maceration	Sealed tank with CO_2 at 30–35°C for 8–15 days	Anaerobic metabolism by berry enzymes	Reducing acid, color, and tannin, improving aroma quality	[40]
Flash evaporation	Heat must to 85–91°C by steam at −0.9 Pa	Break down the skins at high temperature with decompression condition	Increasing the extraction of total phenols, anthocyanidin, and aroma compounds	[41]
Saignée	30% of juice was released after 12 hours	Removing juice to increase skin ratio of red wine	Simultaneous production of dry-red and rose wines, increase the color, aroma intensity, and antioxidant properties of red wine	[42]
Pulsed electric field	3000 Hz, 10 pulse, with 6.5-35kv/cm electric field intensity	Electrical breakdown, electroporation perforated theory	Increasing phenolic profile and wine color	[43]
High hydrostatic pressure	Grapes were subjected to HHP treatments (200-550Mpa) for 10 min	Provide the activation energy for extraction chemical compounds at low temperature without break covalent bonds	Controlled microbial populations, increased phenolic compounds, and anthocyanin extraction, returned higher aromatic quality and color scores in wine	[44]
Withering	Loss of water by 20–40%	Concentrated the grape substance by dehydration	Increased alcohol, residual sugar, and acidity content, improved, phenols, antioxidant activity, brightness, yellow tone, aroma, and taste	[45]

Table 3.
Pretreatment techniques before fermentation.

wine, and beer, and domestic wine production in China has decreased year by year since 2012. It is now a common phenomenon in the global wine industry where total wine production exceeds demand and as such, China's wine manufacturers will continue to face great pressure in the coming years. To preserve the wine market, enologists and researchers must improve wine quality, increase shelf life, and produce new products.

In this chapter, some useful pretreatment techniques, such as berry heterogeneity, cold maceration, carbonic maceration, flash evaporation, saignée, pulsed electric field, high hydrostatic pressure, and withering procedure are further reviewed (**Table 3**).

7. Conclusions

China has become one of the most important wine countries in the world, the history and current situation of Chinese grape and wine industry were reported. According to the meteorological and geographical regionalization, China wine producing area have been categorized into 11 regions, the detailed information of these regions was listed.

In many parts of China, Vitis wild species such as *Vitis amurensis*, *Vitis davidii*, and *Vitis quinquangularis* and their hybrids varieties were wildly planted and used as resistant stock, however, the elaborated wine made from these grapes were quite unlike those made from *Vitis vinifera*, thus, chemical components and wine making technics of wild species were summarized. Finally, the impacts of some pretreatment techniques on *Vitis vinifera* wine composition and quality were reviewed.

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